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CONTROL AND DISPOSAL OF KRAFT MILL EFFLUENTS

by W. A. Moggio

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CONTROL AND DISPOSAL OF KRAFT MILL EFFLUENTS

W. A. Moggio*

The Kraft, or Sulfate, Process is the youngest of the three major methods for making chemical woodpulp. Since the kraft process was first utilized in this country in 1910 there has been a tremendous increase in the size of the kraft pulp and paper industry. In 1935 the capacity for kraft pulp was 2 million tons per year. By 1947 this capacity had expanded to 5.5 million tons per year. In 1952, just 5 years later, the capacity had expanded to 9.5 million tons per year. This capacity represents 50% of the total wood pulp capacity for all grades. Growth of the kraft industry in the South has been phenominal and it is in the South where the production of kraft pulp and paper is centered presently and where the largest mills are located.

Although the manufacture of pulp and of paper are two separate operations they will be treated as one in the scope of this discussion. In the kraft industry the two operations are generally integrated resulting in manufacturing installations where pulp wood enters at one end of the mill and the finished product, paper or paperboard, leaves the mill at the other end.

Raw materials for kraft pulp and paper mills consist of pulp wood, chiefly one of the resinous woods, water, sodium sulfate, lime, sulfur, chlorine, hypochlorites, chlorine dioxide, peroxides, sodium hydroxide, starch, rosin, wax, alum, clay, talc, calcium and barium sulfates, titanium dioxide, zinc sulfide, calcium carbonate, pigments and dyes. The raw materials of greatest significance, insofar as waste effluents are concerned, are the pulp wood, water and sodium sulfate.

Kraft pulp is produced by cooking the debarked and chipped pulp wood in digesters under steam pressure in a solution known as kraft white liquor. Sodium hydroxide and sodium sulfide are the essential ingredients of the white liquor. The concentration of the cooking ingredients, the cooking time and pressure depend on the type of final product desired. The spent cooking liquor, now dark brown in color and known as black liquor, is separated from the cooked pulp by washing, filtering and pressing operations. The dissolved wood substance and the spent cooking chemicals are contained in the black liquor.

The black liquor is processed by evaporation and incineration in order to recover the content of chemicals and in order to utilize the heating value of the dissolved wood substance contained therein. Sodium sulfate, with or without added sulfur, is added during this recovery process to replace the relatively small proportion of the chemicals lost in the various steps of the process. Following these additions and the incineration, the smelt is dissolved in water to form green liquor. The chemical compounds in the green liquor are converted to the desired cooking chemicals by the addition of lime, resulting in the formation of white liquor and a lime mud consisting chiefly of calcium carbonate. The white liquor is returned to the pulping operation as the cooking liquor and the lime mud is calcined to form calcium oxide which is re-used in converting green liquor to white liquor.

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The cooked pulp or fiber which was separated from the spent cooking liquor is screened and subjected to various refining operations, following which it may be bleached. Then it is transported to the paper machine where the fibers are formed into paper or paperboard, the final product. The manufacturing operations are shown schematically in Figures 1 through 6.

Because of the relatively high cost of the chemicals used to prepare kraft cooking liquor, it is necessary to recover the chemicals from the spent cooking liquor if the kraft process is to remain competitive with other types of pulps. Furthermore, as in all competitive industries, success in the kraft pulping industry is largely a question of economics. Economic considerations alone have required the kraft pulping industry to eliminate, or greatly reduce, the losses from the manufacturing operation because all such loss represents relatively expensive raw materials which must be replaced.

The chemicals contained in kraft cooking liquor are equivalent to about 2000 pounds of sodium sulfate per ton of pulp. Present day kraft mills, efficiently operated, will discharge an effluent which contains no more than 5% of the sodium sulfate equivalent of the cooking liquor per ton of pulp, or approximately 100 pounds per ton of pulp. Kraft mills exist today which have losses of sodium sulfate even lower than this figure.

In order to produce one ton of kraft pulp it is necessary to process approximately two tons of pulpwood. The purpose of the pulping operation is to dissolve the non-fibrous portion of the wood, leaving behind the fiber. In kraft pulping, with the coniferous type of wood used, the non-fibrous portion of the wood amounts to approximately 50% of the wood weight. This non-fibrous material is made up roughly of 60% lignin, 30% carbohydrates, 7% resins and fats and the remainder is protein and other minor compounds. During the cooking operation the reactions in the digester consist essentially of the hydrolysis of the lignin and carbohydrates, resulting in the formation of salts which are soluble in water or an excess of alkali. Fats and resins are saponified and are dissolved or carried as suspensions in the black liquor. Some wood alcohol is formed from the hydrolysis of lignin and is released in the digester relief gases along with recoverable quantities of turpentine and small quantities of dimethyl sulfide, methyl mercaptan, and ketones. Sodium salts of formic, acetic and lactic acids are formed by the oxidation of the carbohydrates. In addition to the by-product recovery of turpentine the black liquor contains recoverable quantities of the sodium salts of resin and fatty acids which separate upon the concentration and cooling of black liquor. This material is called crude sulfate soap and after skimming from the black liquor it is treated with acid to form tall oil. The resin and fatty acids obtained are further separated and refined and find application in a wide variety of uses.

In an efficiently operated kraft mill the loss of these dissolved wood substances, consisting chiefly of lignins, carbohydrates and carbohydrate oxidation products, amounts to somewhat less than 5% of the total dissolved wood substance in the black liquor, or about 90 pounds per ton of pulp produced. This loss is found in the kraft mill effluent. A simplified diagram of the solids balance per ton of pulp in the kraft pulping operation is shown in Figure 7.

Present day water use figures for kraft pulp and paper mills are in the range of 20,000-30,000 gallons of water per ton of pulp for unbleached kraft, while for bleached kraft water use figures range from 40,000-60,000 gallons per ton.

The character of kraft mill effluents varies somewhat depending on whether the effluent is discharged from a mill manufacturing bleached or unbleached paper. Suspended solids will range from 20-60 ppm and this will be primarily

fiber. Fiber losses average about 0.5% of the total product produced. Dissolved solids concentrations range from 1000-1500 ppm of which approximately 60% are fixed solids. Effluent B.O.D. values range from 100-200 ppm or 20-40 pounds per ton of product. The effluent is coffee colored and has a color value of approximately 500.

The major pollutional characteristic of kraft mill effluents is its organic matter content which exerts a biochemical oxygen demand. This organic matter oxygen demand is largely attributable to wood sugars, hemi-celluloses and cellulose degradation products found in the effluent. The lignins and tannins found in the effluent exert little or no biochemical oxygen demand. The color of the effluents is attributable to the lignin and tannin compounds. From a stream pollution standpoint these materials are significant only from an aesthetic viewpoint. Kraft mill effluents exhibit no toxic or inhibitory qualities and contain no materials of significance insofar as pathogenic or other bacteria and organisms are concerned. In addition, the effluents are very low in nitrogen and phosphorus compounds which are significant in the growth of algae or slimes in the receiving waters. The individual effluents which influence the character of the total mill effluent to the greatest degree, as a result of their strength and volume, are decker seal pit waters, barometric leg or jet condenser waters from the evaporators, and the white waters from the paper machines.

During the past decade the character of kraft mill effluents has changed tremendously insofar as strength is concerned. Prior to that time it was not unusual to find kraft mills with salt cake losses of as much as 500 pounds per ton of pulp. Water use figures were considerably higher than those prevalent today. Effluent B.O.D. values were in the range of 500 ppm and it was not unusual for effluents to contain more than 100 pounds of B.O.D. per ton of product. Associated with the high losses of salt cake there existed problems of toxicity to aquatic life as a result of the concentration of sulfides, mercaptans and soaps of resin and fatty acids in the effluents. The condition of kraft effluents today is greatly improved. This improvement is due to a variety of reasons such as economic factors, better in-plant effluent control practices, and the development of controlled effluent discharge and effluent treatment methods.

Although the axiom that economy in the manufacturing costs of a competitive product is good business practice, benefits other than just the saving of dollars and cents often result. In the case of the kraft pulp and paper industry, where manufacturing costs are closely associated with the chemical recovery system of the manufacturing process, the greater the portion of spent chemicals recovered economically, the weaker the mill effluent becomes. Thus, the higher the price of the makeup chemical, sodium sulfate, becomes the greater becomes the effort to recover more of it from the spent chemical liquors. Hence, the amount discharged in the effluent becomes less and, correspondingly, less soluble wood substance passes out in the effluent, resulting in a weaker effluent. Such has been the case in the kraft industry in recent years. Therefore, economic conditions are significant in the reduction of effluent strengths.

By-product recovery of turpentine and resin and fatty acids also play small but significant parts in aiding in the reduction of effluent strengths. Maximum recovery of these by-products has resulted in kraft effluents in which chemical toxicants are no longer a factor insofar as stream pollution is concerned.

The most effective measure in the abatement of stream pollution is in the in-plant control of effluent quality from the various manufacturing operations. It is usually cheaper to prevent the discharge of pollutants than it is to treat

the effluent for removal of the pollutants. These preventive measures naturally begin in the manufacturing plant or operation. In-plant control measures in a kraft mill involve certain practices which are applicable to industry in general. These practices include good housekeeping measures, careful control of manufacturing operations, good maintenance of operating equipment, and the proper education of supervisory and operating personnel in the importance of waste control and its significance in pollution abatement. In addition to the above the character of kraft mill effluents has been influenced greatly in recent years as a result of improved manufacturing operations and process equipment and water conservation practices.

A major step was taken in the prevention of spent cooking liquor losses to the sewer with the development and use of multi-stage, vacuum washers, called brown-stock washers, for draining and washing pulp free of spent cooking liquors. This type of pulp washing system operates as a closed system with wash water entering the system at the end opposite to where the unwashed pulp is introduced, and flowing counter-current to the flow of the pulp. No wash water is discharged from this system and the concentration of the dissolved matter in the water is increased to the point where it becomes economical to evaporate it for the recovery of the spent cooking chemicals. This is in contrast to the older and practically obsolete method of pulp washing wherein diffusers were used to wash pulp. These could not be operated economically as a closed system due to the fact that a portion of the wash water, called tail washings, which was relatively low in dissolved solids content, would not be evaporated economically for the recovery of the spent chemicals contained therein. The vacuum filter type of brown stock washers has resulted in less dilution of black liquor and lower heat losses in addition to its advantage as a closed system. Another type of equipment which has resulted in lower sewer losses of black liquor is the foam trap or foam breaker. This type of equipment prevents foam from spilling over and allowing the entrained liquor to find its way to the sewer.

Multiple body evaporators, which are used to concentrate the dissolved solids in the black liquor prior to incineration, have been improved in design. This improvement has resulted in the practical elimination of black liquor carryover due to foaming and entrainment during the evaporation of black liquor. As a result, entrained black liquor does not find its way to the sewer through the evaporator condenser water which is used to produce a vacuum effect in some of the evaporator bodies. Increased capacity of evaporators, permitting the evaporation of larger quantities, and somewhat more dilute, black liquor has also resulted in lower sewer losses of this material. This type of improvement in process equipment is actually a demonstration of the role of economics in improving the quality of a kraft mill effluent. Similarly, better design of evaporators resulting in greater efficiencies and lower operating costs is likewise an economic factor reflected in an improvement in effluent quality.

Many process changes and new or modified process equipment had their origin as a result of the need for water conservation in the manufacturing operations. In some instances, however, the water conservation feature is a secondary result of the new process or equipment. Irrespective of whether the water conservation results as a primary or secondary consideration, water conservation practice in the kraft pulp and paper industry is closely associated with effluent quality improvement. Without getting into a dissertation as to desirability and need for water conservation, it can be said that water conservation practice has a definite effect in decreasing the pollutional characteristics of kraft mill effluents. As a matter of fact, water conservation

practice in the industry owes its origin, in great part, to the industry's desire to solve its effluent disposal and stream improvement problems.

Water conservation in the kraft industry is predicated on the practice of water re-use in the individual process operations throughout the entire manufacturing operation. Through re-use of process waters it is possible to recover some of the pollution-contributing materials which might otherwise be discharged in the effluent. Likewise, re-use of process waters results in smaller effluent volumes which has a definite bearing on the cost of effluent treatment and disposal. Generally speaking, greater water conservation will result in smaller losses of pollution contributing substances to the sewers.

The complete solution to the kraft industry's effluent disposal problem would be in the elimination of the effluents entirely through the practice of complete water re-use and recirculation, that is, by a completely closed system. It is immediately apparent that this solution is fraught with difficulties. Water in continuous recirculation would contain impurities which are constantly augmented. Water quality would deteriorate to the point where it is no longer suitable for the purpose for which it is intended. Some of the troubles resulting from such a tightly closed recirculation system could be excessive bacterial sliming, excess retained heat, reduced paper machine speeds and paper production, excessive foaming, reduced paper quality, sizing difficulties and increased equipment corrosion. Nevertheless, it has been possible to re-use a large proportion of process waters through the judicious use of process and equipment modifications and by other technological means. The development and use of satisfactory bactericides and slimicides has permitted wider latitudes in process water re-use in paper making operations. The re-use of dilute black liquor for liquor volume make-up in digesters and the use of cooling waters from turpentine condensers and condensate from digester blowdown in pulp washing operations have contributed to the reduction of fresh water usage in pulp mill operations. In bleaching operations the effluent from various pulp washing operations is extensively re-used for consistency regulation and stock movement. As previously mentioned, vacuum filter type brown stock washers in the place of diffusers have resulted in a closed system with no sewer discharge. Better evaporator and furnace equipment has also been instrumental in decreasing sewer losses. New or modified equipment permitting refining, transportation and bleaching of pulp stock at higher consistencies have aided materially in water conservation since the volume of water required per unit quantity of pulp is decreased. Improvements in caustic room equipment have resulted in increased efficiencies and have lowered water use and sewer losses. The use of vacuum filters as deckers has also contributed to water conservation by reducing fiber losses in the filtrate, or white water, thereby permitting the re-use of this white water as process water; such as in thinning fresh stock in screening operations.

Special mention should be made of "Save-alls", which may be considered as paper mill process equipment although its application is primarily on paper machine white waters for the two-fold purpose of clarification for white water re-use and for fiber recovery and re-use. Removal of the fiber naturally results in lower sewer losses resulting in effluents of lower pollutional strength. There are four general types in use: stationary and revolving screen save-alls; vacuum filter save-alls; settling or sedimentation tanks; and flotation save-alls. Properly installed and operated save-alls are capable of removing 95% or more of the fiber in white waters. The most generally used type in kraft paper mills is the vacuum filter save-all which is similar to the vacuum brown stock washers and deckers used in the pulp mill. These various water conservation features are graphically illustrated in Figure 1 through Figure 6.

From the foregoing it is immediately apparent that new or modified processes and process equipment have contributed materially to the progress made by the kraft pulp and paper industry in its stream improvement program.

In spite of the progress made in reducing material losses to the sewers by in-plant control measures there remains the problem of effluent disposal. Kraft mill effluents today are considerably weaker in pollutional characteristics than they were a few years ago. The in-plant improvements have eliminated entirely one of the pollutional characteristics, toxicity to aquatic life, and have materially reduced the other characteristic, biochemical oxygen demand. In many instances, where sufficient river or ocean dilution is available, effluent disposal today is simply a matter of discharging it directly to the water body without impairing the quality of the receiving waters. In some cases, however, treatment of the effluent is required on a seasonal or year around basis, as a result of insufficient dilution being available in the receiving waters. It must be kept in mind that kraft pulp and paper production is centered in the South, an area which is subject to wide seasonal fluctuations in river flows, with extremely low flows being encountered in the summer and fall where water and air temperatures are at their peak. In addition, the kraft mills, for economic reasons, are relatively large producers of pulp and paper, with the smallest producing 250-300 tons daily and ranging up to nearly 2000 tons daily. This means that effluent volumes, based on a figure of 20,000 gallons of water per ton of pulp, range from 6 million to 40 million gallons per day. Even with the lower effluent B.O.D. values encountered today, the volume of the effluents pose quite a disposal problem, and in many cases, some form of treatment is required prior to disposal.

The methods for the treatment and disposal of kraft mill effluents presently being used may be classified as follows:

A. Disposal by Dilution

1. Directly to receiving water by uncontrolled discharge.
2. Ponding for release later into receiving water by controlled discharge.
3. Combination of A1 and A2 (when effluent separation is practiced, high B.O.D. effluents disposed by Method A2, remainder of effluent disposed by Method A1.)

B. Treatment By Controlled Natural Stabilization Followed by Disposal to Receiving Water

1. B.O.D. reduction in ponds followed by disposal into receiving water.
2. B.O.D. reduction in small tributary streams or effluent canals followed by disposal into receiving water.
3. Combination of B1 and B2.

In practice the use of ponds as a means of effluent disposal is the most widely used method. From the preceding classification it will be noted that ponds are used to serve one of two functions. Ponds are used in some instances primarily as effluent storage devices, in which the effluent is held until the volume of receiving water is sufficiently great to permit the release of the stored water by controlled discharge. In this manner the quality of the receiving water is not impaired. This method of effluent disposal is used

when stream flows are at a low level for prolonged periods of a predictable nature. Due to the physical character of these storage ponds with respect to their size and depth, plus the nature of the effluent, which is deficient in nitrogenous compounds, little or no B.O.D. reduction is attained upon storage. Storage periods may range in duration from a few months to as much as ten months. Considering the size of present day kraft mills and the volume of effluent per ton of product it is apparent that the storage ponds can be tremendously large. As a result of their size, their use depends on the availability of tremendous land areas. The topographic characteristic of this land is an important factor in the costs involved for the construction of levees to make the area suitable for storage purposes.

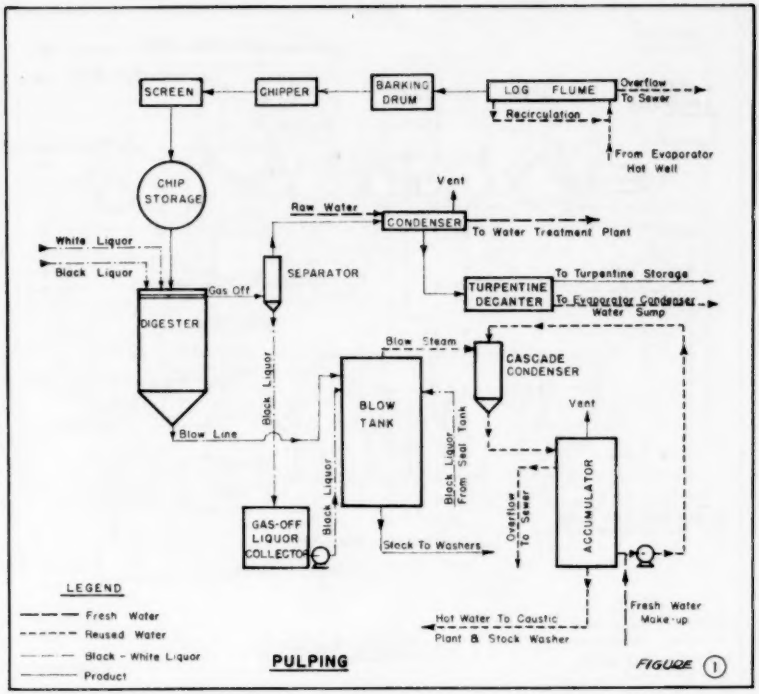
Another application of ponds involves their use as effluent stabilization devices wherein appreciable B.O.D. reductions are attained. The magnitude of the B.O.D. reduction depends on the retention period in the pond, the presence of sufficient nitrogenous compounds to stimulate bacterial activity and the opportunity for some degree of oxygen solution, either through a large ratio of surface area to depth or by agitation. Retention periods in this type of pond may vary depending on the available volume of receiving water and the B.O.D. reduction of the effluent required to permit its disposal without impairing the quality of the receiving water. Retention periods of 10 to 30 days are commonly used. Obviously, the size of these ponds is considerably smaller than that used for storage purposes primarily. Operation of this type of pond is usually seasonal, being used during periods of low stream flows. During higher stream flow periods the effluents are discharged directly to the receiving water by uncontrolled discharge.

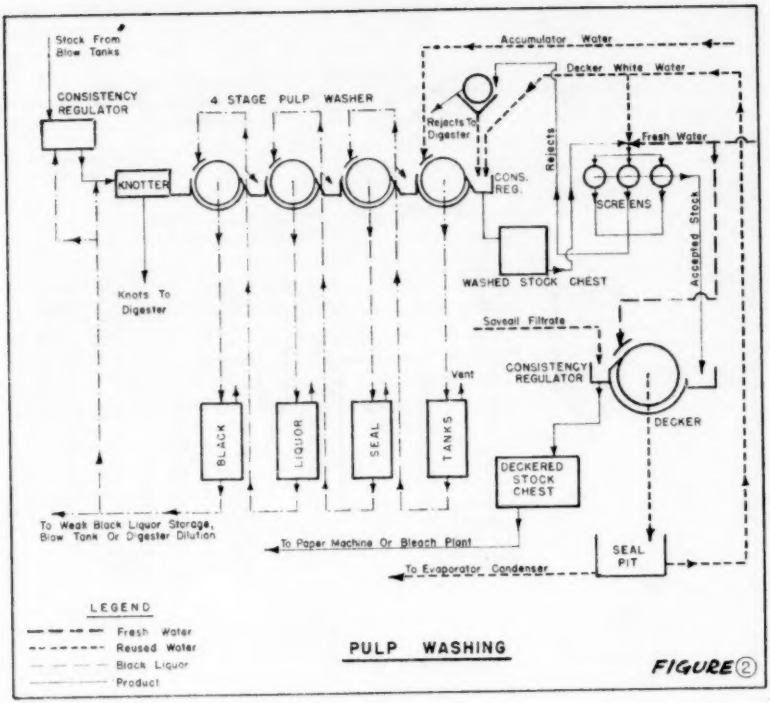
Another method of effluent treatment prior to disposal involves the reduction of B.O.D., by the passage of the effluent in shallow tributary streams or effluent canals. The B.O.D. reduction of the effluent is brought about by microbiological activity and proceeds at an accelerated rate when domestic sewage is present in the tributary or canal. In this instance the domestic sewage is the source of the nitrogenous matter and the necessary microorganisms. The presence of the kraft effluent acts as a source of food supply for the microorganisms and stimulates their growth to such a degree that rapid stabilization of the organic matter from the effluent occurs. This phenomenon was first noted when large concentrations of microorganisms were found suspended in the river water and attached to submerged objects below kraft mill effluent outfalls discharging into rivers or streams receiving appreciable quantities of untreated domestic sewage. Advantage has been taken of this observation and this method of effluent stabilization has been applied as a treatment process in tributary streams and effluent canals, permitting the stabilized effluent to be discharged into the receiving water without impairing its quality.

The foregoing effluent treatment and disposal methods have served the kraft industry satisfactorily. Continued successful operation, however, is dependent to a large extent upon the whims of nature, in providing sufficient river flows for the disposal of the treated and untreated effluents. In addition, during recent years suitable new sites for kraft mills have become increasingly difficult to find and in many instances this has been due to the effluent disposal problems encountered at the proposed mill sites. As a result much effort has been expended in the development of an accelerated treatment process for the stabilization of kraft mill effluents. The development of such a process, which would lend itself to easy control and economical application, would eliminate the vagaries of nature from the effluent treatment and disposal problem. In addition, such a process would serve to make available many locations now considered as unsuitable for new mill sites from an effluent disposal standpoint.

In recent years a promising accelerated treatment process for kraft effluents has been developed by the National Council for Stream Improvement. The process embodies the principle of activated sludge as used for domestic sewage treatment. Some modification of the standard activated sludge process was made, involving the addition of a nitrogen salt, in which the kraft effluent is deficient. The effective microorganisms of the sludge are similar in nature to those of the standard activated sludge process. The settling characteristics and effective temperature range of the sludges differ, however. Development work to date, on a pilot plant basis, has shown the process capable of good B.O.D. reduction, easy control and resistance to upset as a result of shock loads. Its greatest shortcomings are, however, the capital and operating costs involved when the process is applied in the type of structures and operating techniques traditionally associated with the activated sludge process. This is easily comprehensible in the light of the large effluent volumes involved. Presently, further development studies are being directed toward overcoming this drawback through efforts to apply the process in inexpensive structures and by equipment modification. A schematic drawing of the pilot plant used for the basic studies is shown in Figure 8.

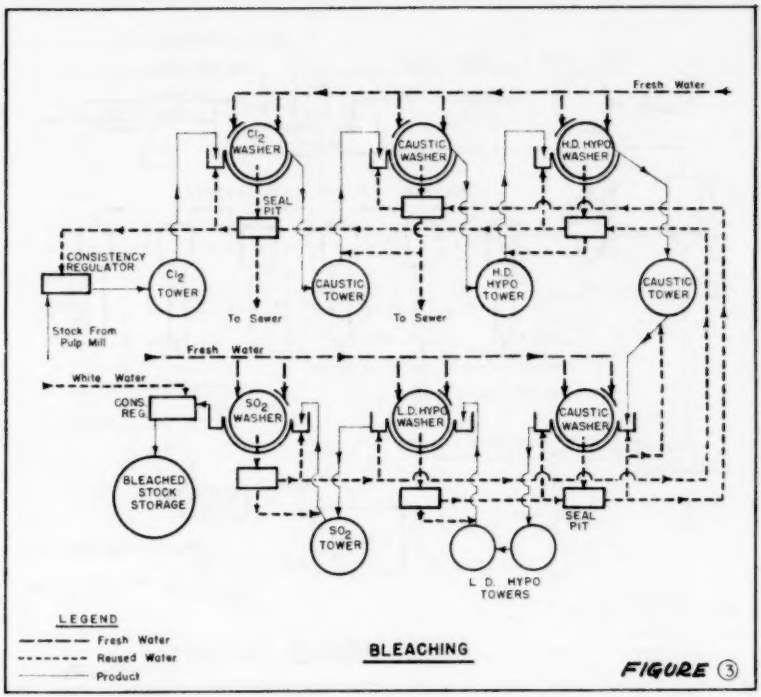
Presently undergoing investigation is the problem of color removal from kraft mill effluents. Color may be removed by treatment of the effluents with high dosages of hydrated lime. This results in large volumes of hydrous sludges which are extremely difficult to dewater and this factor has been a major hindrance in solving the color removal problem. Due to the high lime dosages used it is necessary, for economic reasons, to recover the calcium content of the sludges for re-use. Some promising methods of sludge treatment, involving the use of carbonation and heat, are being pursued.

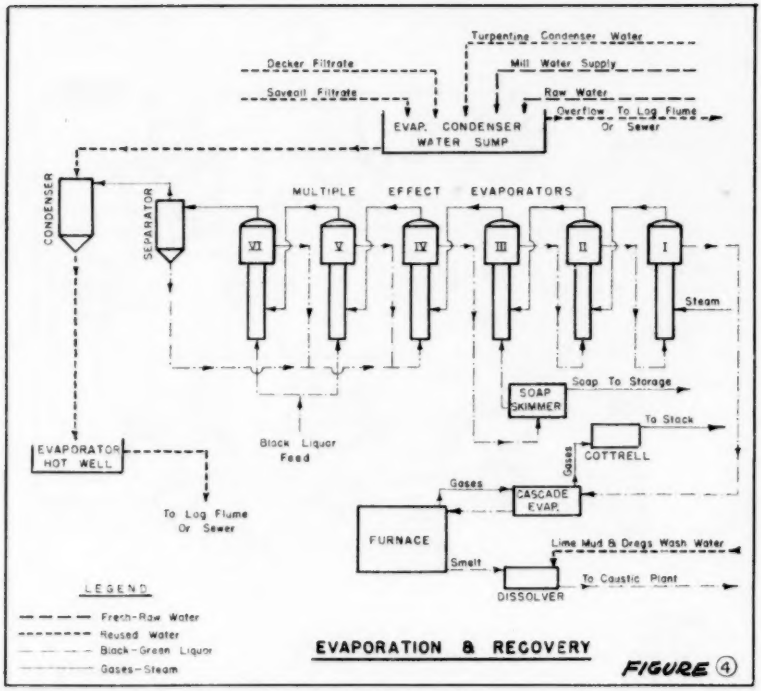

SCREEN
CHIPPER
BARKING DRUM
LOG FLUME
Overflow To Sewer
Recirculation
From Evaporator Hot Well
CHIP STORAGE
Vent
Raw Water
CONDENSER
To Water Treatment Plant
White Liquor
Black Liquor
SEPARATOR
Gas Off
TURPENTINE DECANTER
To Turpentine Storage
To Evaporator Condenser Water Sump
DIGESTER
Blow Steam
CASCADE CONDENSER
Black Liquor
BLOW TANK
Vent
Blow Line
Black Liquor From Seal Tank
Black Liquor
Overflow To Sewer
ACCUMULATOR
GAS-OFF LIQUOR COLLECTOR
Stock To Washers
LEGEND
Fresh Water
Reused Water
Black - White Liquor
Product
Hot Water To Caustic Plant & Stock Washer
Fresh Water Make-up
PULPING
FIGURE (1)



PULP WASHING

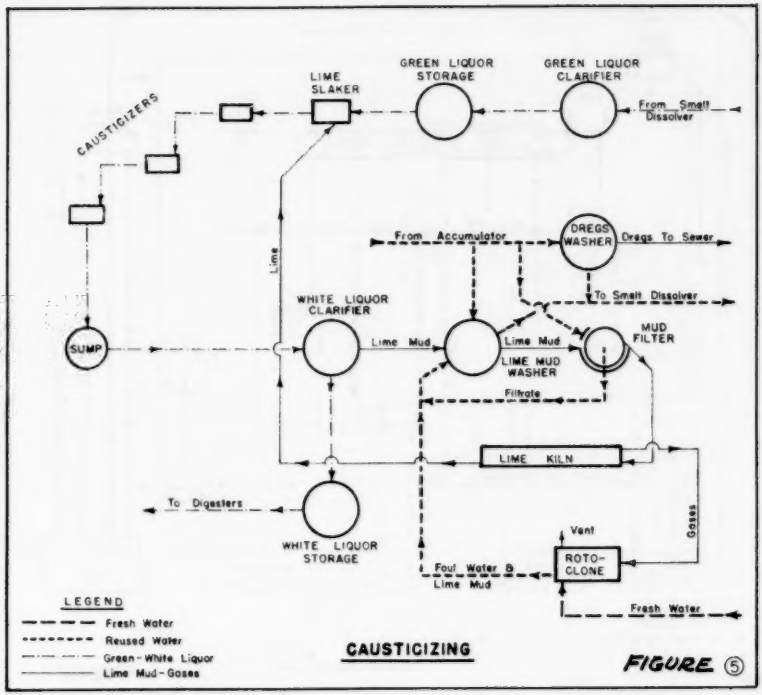
FIGURE ②


Fresh Water
Cl_2 WASHER
CAUSTIC WASHER
H.D. HYPO WASHER
SEAL PIT
CONSISTENCY REGULATOR
Cl_2 TOWER
CAUSTIC TOWER
H.D. HYPO TOWER
CAUSTIC TOWER
To Sewer
To Sewer
Stock From Pulp Mill
Fresh Water
White Water
CONS. REG.
SO_2 WASHER
L.D. HYPO WASHER
CAUSTIC WASHER
BLEACHED STOCK STORAGE
SO_2 TOWER
SEAL PIT
L.D. HYPO TOWERS
LEGEND
Fresh Water
Reused Water
Product
BLEACHING
FIGURE ③



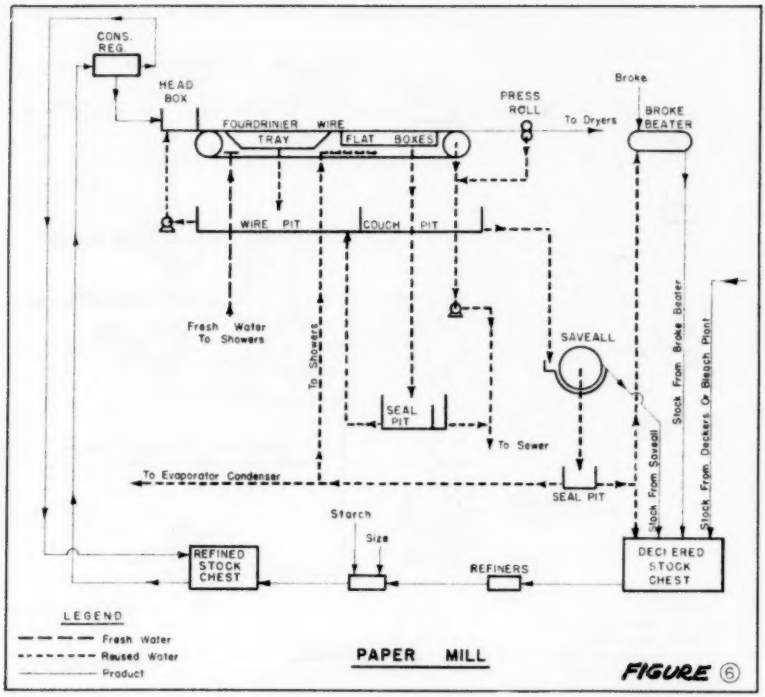
EVAPORATION & RECOVERY

FIGURE ④



CAUSTICIZING

FIGURE ⑤


CONS. REG.
HEAD BOX
FOURDRINIER WIRE
TRAY
FLAT BOXES
PRESS ROLL
To Dryers
Broke
BROKE BEATER
WIRE PIT
COUCH PIT
Fresh Water To Showers
To Showers
SAVEALL
SEAL PIT
To Sewer
To Evaporator Condenser
SEAL PIT
Stock From Saveall
Stock From Broke Beater
Stock From Deckers Or Bleach Plant
Starch
Size
REFINERS
REFINED STOCK CHEST
DECKERED STOCK CHEST
LEGEND
Fresh Water
Reused Water
Product
PAPER MILL
FIGURE 6

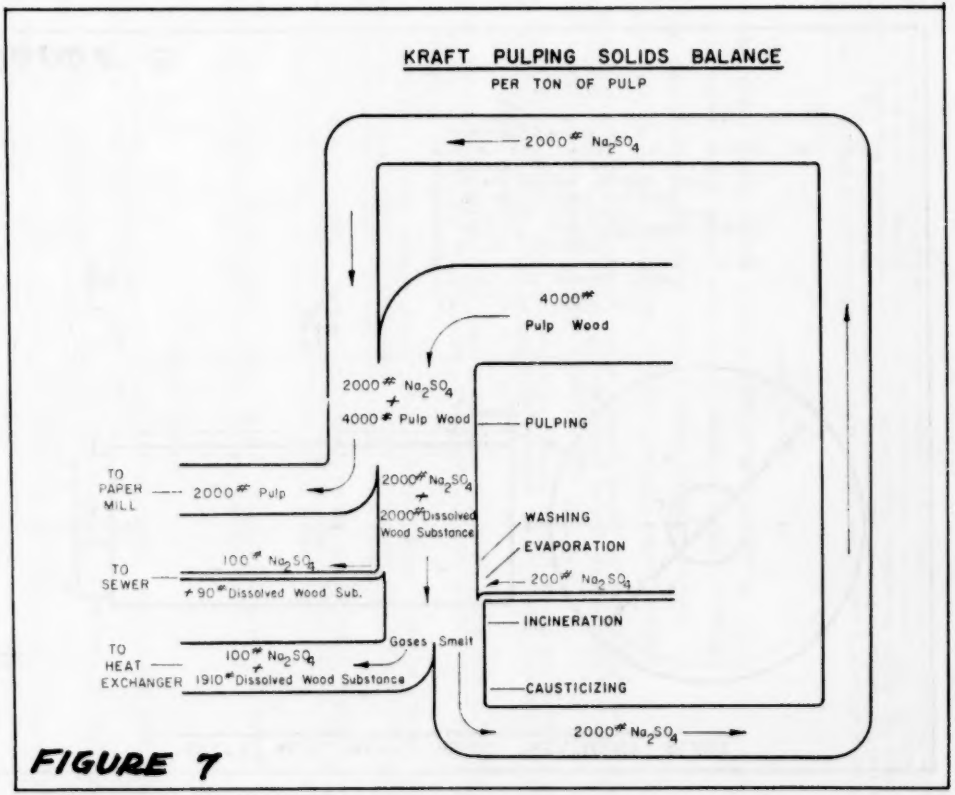
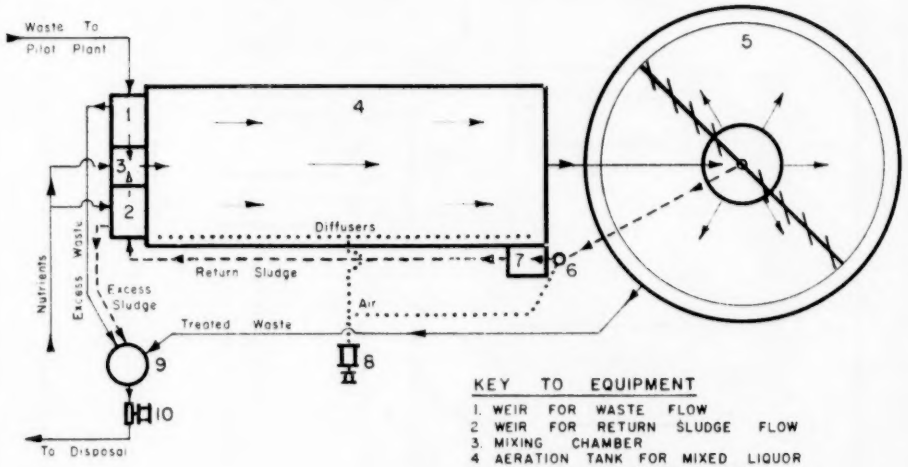

KRAFT PULPING SOLIDS BALANCE
PER TON OF PULP
2000# Na_2SO_4
4000# Pulp Wood
2000# Na_2SO_4 + 4000# Pulp Wood
PULPING
TO PAPER MILL
2000# Pulp
2000# Na_2SO_4 + 2000# Dissolved Wood Substance
WASHING
EVAPORATION
TO SEWER
100# Na_2SO_4 + 90# Dissolved Wood Sub.
200# Na_2SO_4
INCINERATION
TO HEAT EXCHANGER
100# Na_2SO_4 + 1910# Dissolved Wood Substance
Gases
Smelt
CAUSTICIZING
2000# Na_2SO_4

FIGURE 7

KRAFT MILL WASTE PILOT TREATMENT PLANT



KEY TO EQUIPMENT

1. WEIR FOR WASTE FLOW
2. WEIR FOR RETURN SLUDGE FLOW
3. MIXING CHAMBER
4. AERATION TANK FOR MIXED LIQUOR
5. CLARIFIER FOR MIXED LIQUOR
6. RETURN SLUDGE AIR LIFT
7. TOTAL RETURN SLUDGE WEIR
8. ROTARY AIR BLOWER
9. SUMP FOR EXCESS WASTE, SLUDGE AND TREATED WASTE
10. RETURN PUMP TO MILL DISPOSAL SYSTEM

FIGURE 8

PROCEEDINGS-SEPARATES

The technical papers published in the past twelve months are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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MARCH: 176(SA), 177(EM), 178(HY), 179(EM), 180(HY), D-123(HY), D-126(ST), D-128(ST).

APRIL: 181(WW), 182(ST), 184(HY), 185(EM), 186(HY), 187(ST), 188(HY), D-135(HY), D-136(ST).

MAY: 189(HY), 190(HY), 191(CP) & (AT), 192(SM), 193(HY), D-129(PO), D-138(CP), D-145(ST).

JUNE: 194(CP) & (AT), 195(SM), 196(CP) & (AT), 197(HY), 198(ST), 199(EM), D-134(HY), D-141(HY).

JULY: [a] 200(SM)[b], 201(ST)[b], 202(EM)[b], 203(SM)[b], 204(AT)[b], 205(EM)[b], 206(ST)[b], 207(SA)[b], 208(SA)[b], 209(ST)[b], 210(SU)[b], 211(EM)[b], 212(SU)[b], 213(IR)[b], 214(HW)[b], 215(SM)[b], 216(ST)[b], 217(ST)[b], 218(ST)[b], 219(ST)[b], 220(SM)[b], 221(HW)[b], 222(SM)[b], 223(EM)[b], 224(EM)[b], 225(EM)[b], 226(CO)[b], 227(SM)[b], 228(SM)[b], 229(IR)[b].

AUGUST: 230(HY), 231(SA), 232(SA), 233(AT), 234(HW), 235(HW), 237(AT), 238(WW), 239(SA), 240(IR), 241(AT), 242(IR), 243(ST), 244(ST), 245(ST), 246(ST), 247(SA), 248(SA), 249(ST), 250(EM)[c], 251(ST), 252(SA), 253(AT), 254(HY), 255(AT), 256(ST), 257(SA), 258(EM), 259(WW).

SEPTEMBER: 260(AT), 261(EM), 262(SM), 263(ST), 264(WW), 265(ST), 266(ST), 267(SA), 268(CO), 269(CO), 270(CO), 271(SU), 272(SA), 273(PO), 274(HY), 275(WW), 276(HW), 277(SU), 278(SU), 279(SA), 280(IR), 281(EM), 282(SU), 283(SA), 284(SU), 285(CP), 286(EM), 287(EM), 288(SA), 289(CO).

OCTOBER: [d] 290(all Divs), 291(ST)[c], 292(EM)[c], 293(ST)[c], 294(PO)[c], 295(HY)[c], 296(EM)[c], 297(HY)[c], 298(ST)[c], 299(EM)[c], 300(EM)[c], 301(SA)[c], 302(SA)[c], 303(SA)[c], 304(CO)[c], 305(SU)[c], 306(ST)[c], 307(SA)[c], 308(PO)[c], 309(SA)[c], 310(SA)[c], 311(SM)[c], 312(SA)[c], 313(ST)[c], 314(SA)[c], 315(SM)[c], 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

NOVEMBER: 321(ST), 322(ST), 323(SM), 324(SM), 325(SM), 326(SM), 327(SM), 328(SM), 329(HW), 330(EM)[c], 331(EM)[c], 332(EM)[c], 333(EM)[e], 334(EM), 335(SA), 336(SA), 337(SA), 338(SA), 339(SA), 340(SA), 341(SA), 342(CO), 343(ST), 344(ST), 345(ST), 346(IR), 347(IR), 348(CO), 349(SM), 350(HW), 351(HW), 352(SA), 353(SU), 354(HY), 355(PO), 356(CO), 357(HW), 358(HY).

DECEMBER: 359(AT), 360(SM), 361(HY), 362(HY), 363(SM), 364(HY), 365(HY), 366(HY), 367(SU)[e], 368(WW)[e], 369(IR), 370(AT)[e], 371(SM)[e], 372(CO)[e], 373(ST)[e], 374(EM)[e], 375(EM), 376(EM), 377(SA)[e], 378(PO)[e].

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JANUARY: 379(SM)[e], 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)[e], 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)[e], 390(HY), 391(IR)[e], 392(SA), 393(SU), 394(AT), 395(SA)[e], 396(EM)[e], 397(ST)[e].

FEBRUARY: 398(IR)[f], 399(SA)[f], 400(CO)[f], 401(SM)[f], 402(AT)[f], 403(AT)[f], 404(IR)[f], 405(PO)[f], 406(AT)[f], 407(SU)[f], 408(SU)[f], 409(WW)[f], 410(AT)[f], 411(SA)[f], 412(PO)[f], 413(HY)[f].

MARCH: 414(WW)[f], 415(SU)[f], 416(SM)[f], 417(SM)[f], 418(AT)[f], 419(SA)[f], 420(SA)[f], 421(AT)[f], 422(SA)[f], 423(CP)[f], 424(AT)[f], 425(SM)[f], 426(IR)[f], 427(WW)[f].

a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.
b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.
c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
e. Discussion of several papers, grouped by divisions.
f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.

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